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DEVELOPMENT OF A BIRD/AIRCRAFT STRIKE HAZARD ASSESSMENT METHODO--ETC(U)
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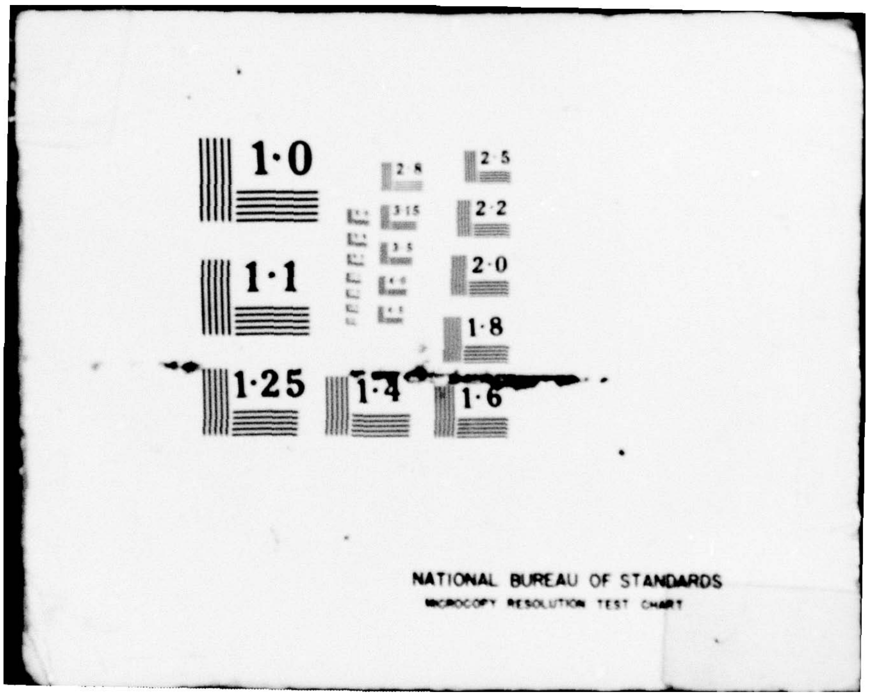
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UNITED STATES AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY
Wright-Patterson Air Force Base, Ohio

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(9) Master's thesis,

(11) 7 Sep 79

(12) 79

(6) DEVELOPMENT OF A BIRD/AIRCRAFT
STRIKE HAZARD ASSESSMENT
METHODOLOGY.

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(14) AFIT-LSSR-10-79B

USAF SCN 75-20B AFIT Control Number LSSR 10-79B

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER LSSR 10-79B	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DEVELOPMENT OF A BIRD/AIRCRAFT STRIKE HAZARD ASSESSMENT METHODOLOGY		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Jeffrey M. Jorgensen, Captain, USAF Kent G. Smith, Captain, USAF		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS School of Systems and Logistics Air Force Institute of Technology, WPAFB OH		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Department of Communication and Humanities AFIT/LSH, WPAFB OH 45433		12. REPORT DATE September 1979 13. NUMBER OF PAGES 67
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) JOSEPH P. HIPPS, Major, USAF 18 SEP 1979 Director of Information		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Bird Strike Hazard Safety Hazard Model Flying Safety Bird Hazard Reduction Methods Civil Engineering		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)		

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

This thesis effort was an attempt to identify a managerial tool that could be used to make decisions when comparing alternative methods of reducing bird/aircraft strike hazards. The general theory was that there should be certain identifiable factors present on a base that affect the probability of a bird/aircraft strike. A relationship was developed by using information from several bases which related to their environment and aircraft operating procedures. Using multiple linear regression, a model was developed to explain how the base's strike rate is affected by these factors. The effort resulted in several conclusions and recommendations that could be used in further research efforts in this area of utmost importance to the Air Force.

LSSR 10-79B

DEVELOPMENT OF A BIRD/AIRCRAFT STRIKE HAZARD ASSESSMENT METHODOLOGY

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Facilities Management

By

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September 1979

This thesis, written by

Captain Jeffrey M. Jorgensen

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has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN FACILITIES MANAGEMENT

DATE: 7 September 1979

Ronald E Kupfer

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ACKNOWLEDGEMENTS

The authors wish to express their thanks to their wives, Bonnie and Carolyn, for their support and encouragement and, in addition, to their children who were constantly asked to be quiet and wait until a later date for more time with their fathers. Additionally, the authors wish to express appreciation to the birds who MADE THE ULTIMATE SACRIFICE.

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CHAPTER I

PROBLEM DEFINITION

Introduction

Since the advent of jet aircraft, the problem of bird/aircraft strikes has become more and more of a concern to the Air Force as well as others who use aircraft (6:xiii). With more traffic, faster aircraft, and engines that are more susceptible to damage from bird/aircraft strikes, the idea of how to reduce this hazard to flying has received a great deal of attention. Much money is spent repairing damage to aircraft as well as trying to reduce the hazard. Possible loss of life or other less severe physiological incidents are also concerns. The Air Force, the Federal Aviation Agency, and many foreign governments and agencies are all trying to reduce this safety hazard (38: 45). The problem is common and the ways to reduce the hazard are varied. The object of this research is to look at a few very specific areas of this problem and perhaps show how this and other research fit together to try to reduce this loss of resources and life.

Problem Statement

A standard method of objectively assessing the effectiveness of bird/aircraft strike hazard reduction methods of

an air base does not exist. Different subjective analyses have been applied to individual facilities to determine the potential for bird/aircraft strike problems and those factors that relate to that potential. The development of a standard methodology which will objectively relate a base's bird/aircraft strike hazard potential with its environment would be a major contribution to Air Force managers.

Justification

> Birds have long been recognized as a potential hazard to aircraft. During the early days of aviation when airplane speeds were relatively slow, damage from bird strikes usually was minor and largely confined to broken windshields and occasional damage to the fuselage. However, since World War II and the introduction of jet aircraft the problem has become more serious. In addition to the greater damage resulting from impact with birds at high speeds, the ingestion of birds in jet and prop-jet engines has become a hazard [4:1].

The above quotation relates that the problem of bird/aircraft strikes increases with the increasing use of jet aircraft. The reliance of the Air Force on jet aircraft and the amount of flying done make the bird/aircraft strikes a concern of decision makers at many levels in the organization. Pilots are concerned about methods that can be employed to avoid a bird strike. Aero-engineers try to design aircraft or modify existing aircraft to reduce the damage of a bird/aircraft strike should it occur. Civil Engineers try to modify the base environment to make it less attractive to birds, subjectively thinking that with less birds, there will be less bird/aircraft strikes. Managers in the Air Force

should be able to make decisions among alternatives which affect the bird/aircraft strike hazard (BASH) potential. Changes to the environment, the design of the aircraft, flight scheduling, operating procedures, and the total mission bring about a corresponding change in bird/aircraft strike possibility. The Air Force manager should be able to take the results of all these studies of changes and assess the value of alternative ways of reducing bird strikes. These methods of reducing bird strikes cost various amounts and have varying degrees of impact on reducing the possibility of a bird/aircraft strike. If a methodology can be developed to relate these different methods of hazard reduction, it would be a tool to help managers decide among alternatives in an objective way.

There seem to be three general approaches to the bird/aircraft strike problem. The first is to try to reduce the numbers of birds in the airspace.

> The US Air Force annually spends millions of dollars for the replacement or repair of aircraft components damaged by bird/aircraft collisions. A large percentage of these strikes occur on or in the vicinity of the airfield. In order to effectively reduce the strike hazard at the airfield, those features which serve to attract birds to the field must be identified and altered. The ecological survey is undertaken to identify the attractants [40:iii].

The second approach is to try to avoid the airspace when the potential for a bird/aircraft strike is high. An example of this would be: "Local night sorties and multiple approaches should be reduced during peak migration periods [12:vi]." In other words, local operating procedures can be used to avoid

the BASH potential. The third approach comes from those trying to reduce the damage done to the aircraft once a strike occurs.

> Though the removal of birds from the path of aircraft during takeoff and landing is being studied, it is not expected to be able to eliminate strikes entirely, and the most practical solution will be to protect the aircraft itself from the type of damage that would cause an accident. This may be done by strengthening the airframe and designing engines which ingest the birds without serious loss of power [42:1].

Clearly there is a great deal of merit to each view of the subject. The problem addressed here will be to find out the degree to which only the first two approaches reduce the BASH problems and how these methods combine or compliment one another.

The Chief of the Air Force's BASH Team[1] at Tyndall Air Force Base, Florida (38) has had several individuals at various conferences on this subject ask him if he knows of any way to evaluate the actual effectiveness of BASH reduction methods. They wonder if it is possible to determine if BASH reduction plans are effective or if they are just "cosmetic" changes which intuitively lead us to believe we are actually reducing the hazard. In discussing this thesis with the BASH Team Chief, he felt that this type of analysis might open the way to evaluate the overall effectiveness of combinations of BASH reduction programs.

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[1]The term BASH will be used to mean the concept of a bird/aircraft strike hazard. The term BASH team will reference this group from Tyndall AFB.

Conceptual Framework

Each section of airspace that is used by an aircraft has a certain potential for posing a bird/aircraft strike problem. This "BASH potential," inherent in that airspace, changes from time to time and is different for all partitions of the total airspace. As an airplane flies through this airspace, it combines with that inherent potential and brings about a certain probability of a bird/aircraft strike. The bird/aircraft strike hazard is the concept that is used to describe this unsafe condition. The BASH is different for all airspaces, for all airplanes, and it is also different for any combinations of these. For example, a C-141 landing at Wright-Patterson Air Force Base at 1800 hours on 25 January 1979 will have a certain possibility of encountering a bird. This possibility depends on the airplane and its maneuver. It also depends on the potential for a strike that exists in that airspace at that time. The amount of damage done depends on the type of bird, where it hits the plane, the speed of impact, etc. It is the combination of all these factors that decide the resulting damage that occurs. If all these factors are accummulated, the result can be designated as a probable danger or not. This relative evaluation is subjective in nature and is inherent in any analysis in the field of safety. Comparisons can, however, be carried out when more than one alternative method of reducing a hazard exists. It is this attempt to reduce the hazard by various methods or by a

combination of methods that is of concern to the groups and agencies studying this problem. They are trying to reduce the BASH by either reducing the BASH potential, avoiding the airspace where or when that airspace has a high BASH potential, or changing the design of the aircraft to reduce the damage that results from a bird/aircraft strike.

The Air Force would like to minimize the total damage done to aircraft as a result of bird/aircraft strikes (40). The cost of damage is a result of how many strikes occur and their respective damages to aircraft. The only way to reduce the total damage to zero would be to either not fly at all or to eliminate all the birds. This, of course, is not the answer. The object then is to minimize the damage done while maintaining the mission and affecting the birds' environment as little as is necessary. There is believed to be a relationship between the damage cost and the changes that can be made to either the mission, the environment, or the airplane (38). BASH reduction methods could be evaluated in almost a benefit-cost ratio analysis. For example, if the total cost of the BASH reduction method is less than the damage savings that result, then that BASH reduction method is probably worthwhile.

Scope

The first item that limited this research relates to the airspace idea just discussed. The total airspace can be thought of as consisting of two general categories. The first

is that area near an airbase, the airdrome. The second category would be all that area used otherwise while enroute from one airbase to another. The basic ideas discussed in the previous section hold in both categories of airspace. The potential for BASH is generally higher in the area near the airbase. According to the literature, the most hazardous flying condition is when an aircraft is close to the ground. Since birds rarely fly at high altitudes, the BASH potential increases as the aircraft approaches the ground.

> Almost 85 per cent of all bird strikes occur during the low altitude portions of flying. Over 50 per cent occur during the takeoff, landing, initial climb, approach, or transitional phases within close proximity of the airfield [28:22].

Environmental manipulation and changes in local operating procedures are two ways to reduce the BASH and will have its most affect in the airspace near the base. For these reasons, the scope of this research concerns itself only with that airspace near the airbase. This thesis defines near the airbase as a five-mile radius from the airbase, which is the legal control zone area.

The second item that limited this research related to the three general approaches to the reduction of the bird/aircraft strike problems that were discussed in the justification section. The third approach, which deals with trying to reduce the damage to aircraft once a strike occurs, was not in the scope of this research. Attempts to reduce damage to aircraft include such things as design changes to engines or the bird-proofing of canopies and are usually not under the

control of base level managers. The design projects are important, but since they do not affect the BASH potential of a base or the probability of a bird/aircraft strike, they were beyond the scope of this research. Damage cost was explored, however, since it relates to the cost of reducing the hazard. The design projects which attempt to reduce that damage cost once a strike occurs were not considered.

In summary, only those items that affect the BASH potential of an airbase and those local procedures that affect how the pilots avoid the possibility of a bird/aircraft strike were included in the scope of this research.

CHAPTER II

BACKGROUND

Literature Review

A preliminary literature review uncovered many bird/aircraft strike hazard studies performed since the advent of the jet aircraft in the late 1940's. Most of the information relevant to the proposed research, however, was developed in the last 15 years. The information ranged from bird migration surveys to very detailed ecological surveys of airfields.

The Federal Aviation Agency (45) and the Air Force (19) both conducted extensive research studies in the mid 1960's. Data were collected on bird migration, aircraft damage, species of birds encountered, phase of operations, location, and many other pertinent factors. From these data, the capability to predict the most dangerous flying situations was developed. In addition, certain geographical areas such as coastal regions, large rivers, and marshy areas were found to be more hazardous than others. Methods were also recommended to reduce or eliminate bird/aircraft strikes while enroute or in the vicinity of airfields. Similar studies continued through the 1970's by both organizations.

Testing began in the late 1960's and has continued to the present to help design "bird-proof" aircraft. By

simulating bird strikes, useful information was obtained that has helped in the redesign of canopies and other bird vulnerable portions of an aircraft (34:24-25).

In recent years the Air Force established the Bird/Aircraft Strike Hazard Team at the Air Force Civil Engineering Center, Tyndall Air Force Base, Florida. This BASH team performs ecological surveys at seven to ten bases a year.

> The purpose of the ecological survey in the airdrome and the vicinity is to determine how the life forms and environment influence the bird-aircraft strike hazard; specifically, what features of the airfield influence the activity of the birds in the area [40:1].

Birds invade an airdrome to feed, drink, nest, roost, or loaf. When their flight paths between feeding, watering, and sheltering areas cross critical airspace, such as aircraft takeoff and landing paths, then a BASH is present. The BASH team studies the topography, bird species and habits, and the routine flightpaths in the airdrome and vicinity. The team then identifies the problem birds, the areas or factors that serve as bird attractants, and the position on the field that the bird hazard is the highest. As a result of these surveys, recommendations of changes or elimination of the local bird attractants are made. The individual units are also given recommended modifications to their local operational procedures. For example, the BASH team recommended that the low areas on the airfield at Dover Air Force Base be filled and planted to reduce water collection and bird attraction (12: vi). At Malmstrom Air Force Base (14:iv), the team recommended that departing aircraft execute maximum climbs to above

3000 feet above ground level to allow minimum exposure to the majority of local birds.

From the literature review, it was discovered that the environmental factors believed to affect the BASH potential can be placed into eight categories:[2]

1. Natural water bodies
2. Artificial water bodies
3. Natural food sources
4. Artificial food sources
5. Sheltering/nesting areas
6. Migratory route
7. Precipitation
8. Temperature

These categories and their factors will be discussed in the next chapter.

Each base will have factors present from some or all of these categories. The BASH potential of each base is then some function of the factors present. In the past studies it appeared that reduction or elimination of factors within the environmental categories helped reduce the BASH potential. As mentioned earlier, the job of the BASH team is to make recommendations to help reduce or avoid this potential. The recommendations found throughout the literature review are similar, although not as thorough in content, as those in the

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[2] Categories were determined from accumulation of information from cited reference numbers 7, 9-16, 20-26, 31, 32, 48-50.

BASH team studies.

The most common methods of reducing the BASH potential are changing or eliminating the factors in the first five categories previously listed. Migratory routes, precipitation, and temperature are obviously considered unchangeable. In addition, the development of bird-scaring techniques or actual bird elimination actions are also used to reduce the BASH potential. Elimination of birds is usually frowned upon by groups concerned with environmental protection and, therefore, is rarely used.

Since aircraft must fly to accomplish the mission, operating procedures are formulated that attempt to avoid the BASH potential that is present. As mentioned earlier, specific recommendations for changes in a particular base's flying procedures are stated in all BASH team studies. Most other literature also dealt with general recommendations for all aircraft. Certain general methods are used to avoid the BASH potential. The most common methods are as follows (see footnote 2):

1. Changes in flying procedures
2. Altered airdrome traffic patterns
3. General pilot education programs
4. Reduction of flying activities during certain times
5. Establishment of Bird Watch procedures

Further discussion of how these different methods apply to this research can be found in Chapter III.

The Air Force Inspection and Safety Center (AFISC) at

Norton Air Force Base maintains computer files with pertinent information of Air Force bird/aircraft strikes. Prior to January 1978, Air Force Regulation 127-15 (44) required that all bird/aircraft strikes resulting in damage greater than $300 be reported to the AFISC to be maintained in the computer files. Starting in January 1978 this regulation was changed, requiring that all bird/aircraft strikes, no matter what the cost, be reported to AFISC. Information on all the reported bird/aircraft strikes for the years 1974 through 1978 was obtained (1; 2). For each bird/aircraft strike, it contains a short description of what happened, the type of aircraft involved, the damage done, the flying maneuver, and other pertinent facts.

The Air Traffic Service of the Air Force Communication Service at Scott Air Force Base maintains computer files for all the present and past numbers of flying activities (approaches, takeoffs, landings, touch and goes, and so on) for each Air Force base. The numbers of activities for the years 1974 through 1978 were obtained (3). With this information and the information obtained from Norton Air Force Base, a base's probability of a bird/aircraft strike or strike rate was computed. This will be discussed further in Chapter III.

The literature review revealed that the bird studies in the last 15 years appear to be subjective in nature. A large amount of data have been collected from actual bird/aircraft strikes, ecological studies, migration studies and so on. However, little research, if any, has been performed

to develop a methodology for relating a base's BASH with its mission and environment. "Presently no established criteria exists for gauging whether an individual facility has a bird/aircraft collision problem or not [12:1]." This was verified in a telephone conversation with the BASH Team Chief (38).

Objectives

1. Determine the environmental factors which influence the potential for a bird/aircraft strike.

2. Determine the effect that the changing of environmental factors and local operating procedures have on the possibility of a bird/aircraft strike.

3. Develop a methodology which will relate any base's bird/aircraft strike hazard with its mission and environment.

4. Apply the methodology to show how it can aid the manager in decisions related to aircraft operations or environmental manipulation.

Research Questions

What environmental factors can be identified which influence the potential for a bird/aircraft strike?

How is the possibility of a bird/aircraft strike affected by changing certain environmental factors and local operating procedures?

What methodology can be developed that uses the identified mission and environmental factors as a management decision-making tool?

CHAPTER III

METHODOLOGY

Introduction

The categories of observations (Natural Water Bodies, Migratory Routes, etc.) and BASH potential reduction methods discussed in the previous chapter are the variables defined in this chapter. Items such as natural food sources and artificial water bodies are variables that combine together to define the BASH potential of an airbase. With the exclusion of the precipitation, temperature, and migratory route, and the inclusion of scare techniques and the elimination of birds, the list becomes the variables that can be changed to reduce the BASH potential of an airbase. The other variables are the methods employed to avoid the BASH potential such as establishing a "bird watch." All of the variables combine together to define a possibility of a bird strike or a bird strike rate. This relationship and the methodology of how to come up with this relationship is the subject of the rest of this chapter. The data collection methods and the variables are conceptually defined first. They are then operationally defined with the measurement scale for each of the variables.

Each of the variables listed exist in nature as continuous variables. As they are operationally defined for

measurement, the factors that combine to form the variables are on nominal or ordinal scales. The nominal scale is the lowest and least powerful of the scale types and refers to partitioning data into subsets or categories with no indication of order or magnitude. An example is the variable migratory route, which classifies a base into a yes or no category. The ordinal scale is the next highest type of scale that has the unique characteristics of a nominal scale but also indicates order. Using this scale implies a statement of "greater than" or "less than" without any knowledge of how much greater or less. Indicating that one factor of a variable has a greater significance as a bird attractant than another factor of the same variable is an example of an ordinal scale. The combining of the factors used to measure each variable provided for the variables to be classified with an ordinal scale.

Variables

The literature review identified eleven categories of factors that can contribute toward the bird/aircraft strike potential of an airdrome. These categories are the independent variables for the research. The dependent variable is strike rates of each airdrome. The following section identifies and conceptually defines the independent variables followed by the dependent variable.

Independent Variables

Natural Water. This variable identifies the water accumulations which are caused by nature. The factors involved in

this variable are oceans, lakes/ponds, rivers/streams, marshes/swamps, and other natural accumulations.

Artificial Water. This variable identifies the water accumulations which are present because of man. The factors involved are reservoirs, sewage holding ponds, irrigation systems, drainage systems, and other man-made water accumulations.

Natural Foods. This variable identifies the food sources provided by nature. The factors involved are small animals, seed-bearing plants, fruit-bearing plants, insects, and other natural foods.

Artificial Foods. This variable identifies the food sources provided by man. The factors involved are landfill/garbage dumps, sewage systems, farm fields, orchards, vineyards, and other man-provided food sources.

Sheltering. This variable identifies the natural or man-caused vegetation/foliage present which provides sheltering and nesting habitats. The factors involved are trees, shrubs, grasses, ground cover, and others.

Migratory Route. This variable identifies a base's location with respect to a bird migration route. The factors involved are categorized as "in flyway" or "not in flyway."

Precipitation. This variable identifies a base's annual average precipitation in inches.

Temperature. This variable identifies a base's annual average temperature in degrees Fahrenheit.

Scaring Techniques. This variable identifies the

methods used to scare birds from an airfield. The factors involved are personnel teams, remote devices, and other.

Elimination Techniques. This variable identifies the methods used to eliminate birds. The factors involved are hunting, poisoning, nest disruption, predators, and other elimination techniques.

Operational Methods. This variable identifies the methods used by a base to avoid the BASH potential. The factors involved are special flying procedures, special airdrome traffic patterns, pilot education programs, flying reduction programs, bird watch programs, and other.

Dependent Variable

Strike Rate. This variable identifies the number of bird strikes per aircraft activity at an airfield. The bird strikes counted occurred only within a five-mile radius of an airfield.

Variable Operational Definitions

The value given to a particular independent variable will come from an evaluation of the base by using the tables that follow. The factors relating to each variable are rated according to the given scale. The sum of all the ratings for the factors for a particular variable becomes the value for that variable. If a factor is not present at an airfield, then zero is entered as the rating for that factor prior to summing. How the ratings are obtained will be further explained following the tables in the Data Collection section.

TABLE 1

VARIABLE - NATURAL WATER - NATWAT[3]

Factors - Ratings are according to proximity to airbase in miles.

		Rating
OCEAN		
Within 10	3	
10 - 20	2	
20 - 30	1	
Further than 30	0	______
LAKE/POND		
Within 1	3	
1 - 5	2	
5 - 10	1	
Further than 10	0	______
RIVER/STREAM		
Within 2	3	
2 - 5	2	
5 - 10	1	
Further than 10	0	______
MARSH/SWAMP		
Within 2	3	
2 - 5	2	
5 - 10	1	
Further than 10	0	______
OTHER		
Within 1	3	
1 - 3	2	
3 - 5	1	
Further than 5	0	______
	NATWAT = Total	______

[3] In all tables the variable name will be followed by the abbreviation to be used as its computer variable name

TABLE 2

VARIABLE - ARTIFICIAL WATER - ARTWAT

Factors - Ratings are according to proximity to airbase runway in miles.

		Rating
RESERVOIR		
Within 1	3	
1 - 5	2	
5 - 10	1	
Further than 10	0	______
SEWAGE HOLDING PONDS		
Within 1	3	
1 - 5	2	
5 - 10	1	
Further than 10	0	______
IRRIGATION SYSTEMS		
Within 1	3	
1 - 3	2	
3 - 5	1	
Further than 5	0	______
DRAINAGE SYSTEMS		
Within 1	3	
1 - 3	2	
3 - 5	1	
Further than 5	0	______
OTHER		
Within 1	3	
1 - 3	2	
3 - 5	1	
Further than 5	0	______
	ARTWAT = Total	______

TABLE 3

VARIABLE - NATURAL FOODS - NATFOOD

Factors - Ratings according to the concentration of the factors within five miles of the airbase runway

	High	Medium	Low	None	Rating
SMALL ANIMALS	3	2	1	0	____
SEED BEARING PLANTS	3	2	1	0	____
FRUIT BEARING PLANTS	3	2	1	0	____
INSECTS	3	2	1	0	____
OTHER	3	2	1	0	____
		NATFOOD = Total			____

TABLE 4

VARIABLE - ARTIFICIAL FOODS - ARTFOOD

Factors - Ratings according to proximity of the factors within so many miles

	Within 1	1-3	3-5	Over 5	Rating
LANDFILLS GARBAGE DUMPS	3	2	1	0	____
SEWAGE SYSTEMS	3	2	1	0	____
FARM FIELDS	3	2	1	0	____
ORCHARDS	3	2	1	0	____
VINEYARDS	3	2	1	0	____
OTHER	3	2	1	0	____
		ARTFOOD = Total			____

TABLE 5

VARIABLE - SHELTERING - SHELTER

Factors	- Ratings according to the concentration of the factors within five miles of the airbase runway				
	High	Medium	Low	None	Rating
TREES	3	2	1	0	____
SHRUBS	3	2	1	0	____
GRASSES	3	2	1	0	____
GROUND COVER	3	2	1	0	____
OTHER	3	2	1	0	____
		SHELTER = Total			____

TABLE 6

VARIABLE - MIGRATORY ROUTE - MIGRTE

Variable takes on the value of 1 if the airfield can be considered to be in a migratory route, otherwise this variable is 0.

MIGRTE = ________

TABLE 7

VARIABLE - PRECIPITATION - PRECIP

Ratings are according to the average annual inches of precipitation recorded at the airbase.

Over 40 in.	3
20 - 40 in.	2
10 - 20 in.	1
Under 10 in.	0

PRECIP = ________

TABLE 8

VARIABLE - TEMPERATURE - TEMP

Ratings are according to the average annual temperature in degrees Fahrenheit recorded at the airbase

Over 60 deg.	3
40 - 60 deg.	2
20 - 40 deg.	1
Under 20 deg.	0

TEMP = ________

TABLE 9

VARIABLE - SCARING TECHNIQUES - SCARTEC

Factors - Ratings are according to amount of equipment for the scaring team in the first factor and according to the effectiveness of the devices used for the second factor.

		Rating
PERSONNEL TEAMS		
Highly equipped	3	
Moderately equipped	2	
Little or no equipment	1	
No team	0	____
REMOTE DEVICES		
Highly effective	3	
Moderately effective	2	
Slightly effective	1	
Not effective	0	____
OTHER		
Highly effective	3	
Moderately effective	2	
Slightly effective	1	
Not effective	0	____
	SCARTEC = Total	____

TABLE 10

VARIABLE - ELIMINATION TECHNIQUES - ELIMTEC

Factors - Ratings according to degree of development of elimination program		Rating
HUNTING		
Highly developed	3	
Moderately developed	2	
Slightly developed	1	
No program	0	____
POISONING		
Highly developed	3	
Moderately developed	2	
Slightly developed	1	
No program	0	____
NEST DISRUPTION		
Highly developed	3	
Moderately developed	2	
Slightly developed	1	
No program	0	____
PREDATORS		
Highly developed	3	
Moderately developed	2	
Slightly developed	1	
No program	0	____
OTHER		
Highly developed	3	
Moderately developed	2	
Slightly developed	1	
No program	0	____
	ELIMTEC = Total	

TABLE 11

VARIABLE - OPERATIONAL METHODS - OPERMED

Factors - Ratings according to emphasis placed on program and degree of program development.

		Rating
SPECIAL FLYING PROCEDURES		
High	3	
Moderate	2	
Low	1	
None	0	______
SPECIAL AIRDROME TRAFFIC PATTERNS		
High	3	
Moderate	2	
Low	1	
None	0	______
PILOT EDUCATION PROGRAMS		
High	3	
Moderate	2	
Low	1	
None	0	______
FLYING REDUCTION		
High	3	
Moderate	2	
Low	1	
None	0	______
BIRD WATCH PROGRAMS		
High	3	
Moderate	2	
Low	1	
None	0	______
OTHER		
High	3	
Moderate	2	
Low	1	
None	0	______
	OPERMED = Total	______

Data Collection

The data for determining the value of each of the independent variables came primarily from the BASH team studies discussed previously. The information that was not found in the BASH studies that was needed for analysis of the variables was obtained by calling the various bases and talking to individuals who were familiar with the bird/aircraft strike problem for their particular base. The individuals who were most knowledgeable about the BASH studies were usually the base's Flying Safety Officer, the Chief of Operations, or the Chief of Environmental Planning. This first effort of data collection yielded the values for most of the variables. The information obtained in these ways was assumed to give the value for each of the variables in all of the years prior to the BASH studies. The values of the variables for the years after the BASH studies were obtained by calling the above individuals on the bases to see if the recommendations proposed by the BASH team were put into effect. If these recommendations had been carried out or if the base had done other things that would change the ratings on the factors, then this was noted, and the variables were changed for the years following the BASH study for that particular base. The variables Migratory Route, Precipitation, and Temperature were obtained in a more objective manner. As these variables are assumed unchangeable by man's intervention and fairly constant over time, the values for these variables were available from more conventional sources such as

meteorological records. These variables will be referred to as the unchangeable variables.

The various bases' bird/aircraft strike rate (the dependent variable) was computed for each year under study by combining information from the applicable Norton AFB computer outputs (1; 2) and information on the activities of the base's airdrome obtained from Scott AFB (3). The strike rate is simply the number of strikes divided by the number of activities for that year. Each base will, therefore, have five data points, one for each of the five years. With the twelve bases under study, that will provide a sample of sixty combinations of dependent and independent variables.

Validation

The method of data collection just described seems to be quite a subjective way of obtaining the values for these variables. A more objective method is a good topic for additional research, but is beyond the scope of this thesis. To add credibility to this method of analysis, internal validation of the method was accomplished. Each of the values for the factors, except the unchangeable variables, was decided upon by the two researchers independently of one another. As the BASH study reports were read, each researcher marked down what he felt was the value that should be associated with that factor for that particular base. This provided two independently obtained sets of values for all the changeable variables. Once this was completed, the researchers

discussed the discrepancies and came up with a value for each factor that was agreeable to both. This third set of values by consensus was the value of the factor finally used in the analysis.

To validate this method of obtaining the data, the three different combinations of values obtained were analyzed with the sign test to show independence. It was desired to show that no matter which researcher did the analysis or whether they did it together, the values of the variables would not be significantly different. This internal validation should not be confused with external validation of the model to be discussed later. This internal validation is only a check on the method of coming up with the values of the factors making up most of the variables.

The sign test is the strongest test possible for showing the independence of the three times that the values of the factors were determined. The sign test is applicable since the data can be compared in matched pairs of related samples. Each researcher was using the same scale for each of the factors and was referencing the same BASH study. There is no underlying distribution for the data and the data obtained in this manner was all ordinal data. According to Siegal (39:68), "The only requirement is that within each pair the experimenter has achieved matching with respect to the relevant extraneous variables." This requirement is fulfilled in that each of the factors that combined to make up the variables was determined using the same scale and source. In other words, researcher A

evaluated a particular factor from the same BASH report that researcher B used.

The null hypotheses for the sign tests are as follows:

1. $p(X_A > X_B) = p(X_A < X_B) = \frac{1}{2}$

2. $p(X_A > X_C) = p(X_A < X_C) = \frac{1}{2}$

3. $p(X_B > X_C) = p(X_B < X_C) = \frac{1}{2}$

where

p represents "the probability of"

X_A, X_B, X_C represent the values of the factors for the two researchers, A and B, and the combined value C

In this way, the values obtained by the two researchers are compared against each other, and they are also compared individually against the values obtained by consensus and agreement. Each hypothesis had to fail to be rejected to allow the conclusion that the method of obtaining the values of the factors was independent of the researcher and, therefore, valid enough for the purposes of this research effort.

The test was a two-tailed test, and the hypotheses would be rejected if the test statistic were outside the limit for the test at an alpha value of 0.05. Discussion of the results can be found in Chapter IV.

Methodology of Analysis

The data, once collected, were placed on a computer file. The data lent itself to analysis by multiple linear

regression with the dependent variable of Strike Rate and eleven independent variables. The general model for regression would be of the form:

$$Y_{ij} = B_0 + B_1X_{1ij} + B_2X_{2ij} + \ldots + B_{11}X_{11ij}$$

where

Y_{ij} is the strike rate at a particular base i for a particular year j,

B_0 is an autonomous strike rate constant not related to the variables in the model,

B_1 through B_{11} are the coefficients for the variables one through eleven,

X_{1ij} through X_{11ij} are the values of the variables one through eleven of each base i in a particular year j.

A multiple linear regression was used to reveal which of the variables, if any, was significant in predicting the base's strike rate. It also reveals whether the entire model is a significant way of estimating the strike rate. The level of determining significance of the entire model as well as the individual variables was set at an alpha level of 0.05. If some of the changeable variables, such as Elimination Techniques, turned out to be significant, then the model should be usable in determining how the changing of the environment would affect the possibility of a bird/aircraft strike. For example, if Elimination Techniques is a significant estimator of the strike rate and if its coefficient was relatively large, this would show that the use of elimination techniques

was an effective way of controlling the bird/aircraft strike rate of an air base. Thus, a significant model would be a methodology of relating a base's bird/aircraft strike hazard with its mission and environment.

External validity was to be shown by using the model to predict the strike rate for five different groups of variables selected at random and not included in the development of the multiple linear regression model. If the model did not turn out to be a valid predictor of a base's strike rate, then it was intended not to be necessary to show this external validity. In either case, however, some of these randomly selected data points were to be developed into hypothetical situations that might be faced by managers in the Air Force. The purpose of providing these situations was to show how a model such as this could be used in managerial decision-making.

CHAPTER IV

FINDINGS AND ANALYSIS

Internal Validation of Methodology

The methodology used to determine the values of each of the factors that sum to the value of each of the variables in the bird/aircraft strike model was discussed in the previous chapter. In this methodology, each researcher first determined the value of all of the factors independently of each other. They then agreed on a third set of values for the factors. This third set would be the set used in the multiple linear regression model. For example, researcher A evaluated a particular base using the BASH study for that base. He assigned a value to each factor as discussed in Chapter III. Researcher B did the same, the two compromising on a final data set. The data set finally used in the multiple linear regression model can be found in Appendix A. This file is the accumulation of the factors making up the various variables as they were decided upon by the two researchers.

The results of the sign test discussed in Chapter III and other information concerning the validity of the methodology just described are summarized on Table 12. From this table, one can see that there was essentially no difference

TABLE 12

SIGN TEST RESULTS IN COMPARING METHOD OF OBTAINING VALUES FOR FACTORS

Comparison	Hypothesis Number	"z"*	Independence Shown?	Percent of Ties
Researcher A to Researcher B	1	1.0876	Yes	77.78
Researcher A to Agreement	2	11.3348	No	82.05
Researcher B to Agreement	3	3.7143	No	89.53
Researcher A or B to Agreement	None	N/A	N/A	96.15

*The test statistic "z" was compared to a z-critical of 1.96

between the data values obtained by researcher A and researcher B. However, one cannot say from the sign test alone that the set of values obtained by agreement was the same as that obtained separately by each researcher. It was concluded instead that the data obtained by agreement is different and not independent. The sign test analysis is, however, a little misleading in that it ignores the large numbers of ties that occur. Indeed, there were ties in about 80 percent of the cases when comparing either researcher with the agreed-upon values or when comparing the two researchers against one another.

The last line in the table above was added to show that

the agreed-upon set of values for the factors agreed with either one researcher or the other over 96 percent of the time. Much of the remaining disagreement came as a result of telephoning for additional data from several bases. This data was only obtained after both researchers had come up with values for all the factors and, therefore, it was used in figuring the agreed-upon values only. Therefore, one can safely conclude that the methodology used to determine the values for the variables could be replicated quite accurately, especially if done by some scheme involving more than one person as was the case in this research.

Statistical Evaluation of Data

A statistical multiple regression was performed on the data in Appendix A using the computer program in Appendix B. As explained in Chapter III, five data sets were randomly chosen to be excluded from the regression model. The five sets that were excluded can be seen in Appendix A.

The program for the regression was developed using the Statistical Package for the Social Sciences (SPSS)(33) and employs a regression subprogram. In an attempt to determine the independent variables that were most significant in affecting the dependent variable, STRAT, the program was designed to enter the independent variables into the overall equation in a stepwise inclusion. When using stepwise inclusion, the independent variable determined by the computer to explain the greatest amount of variance in the dependent variable was

entered into the regression equation first. Then the variable that explained the greatest amount of variance in conjunction with the first was entered second and so on until all eleven independent variables were entered into the equation. The order that the independent variables were entered into the equation can be seen in Table 13 along with other statistics that will be discussed in this section.

From column 2 in Table 13, the regression model developed by the computer is:

$$\begin{aligned} \text{STRAT} = (&-742.0 + 251.4\ \text{TEMP} + 58.3\ \text{NATWAT} - 20.3\ \text{OPERMED} \\ &+ 310.4\ \text{MIGRTE} - 37.1\ \text{SHELTER} - 108.1\ \text{PRECIP} \\ &+ 27.4\ \text{ARTWAT} + 67.6\ \text{SCARTEC} - 32.9\ \text{ELIMTEC} \\ &+ 10.0\ \text{NATFOOD}) \times 10^{-7*} \end{aligned}$$

Visually analyzing this model revealed some expected and unexpected relationships. The independent variables with positive coefficients show a direct relationship with the dependent variable, STRAT. Therefore, as the value of any of these independent variables increases, it increases the value of STRAT. One direct relationship which was unexpected in the model was that of SCARTEC. The model shows that by increasing scaring techniques, the bird/aircraft strike rate will increase. Of course, for this to be logical with what actually occurs in nature, it should be an inverse relationship. Increasing the value of these independent variables

*See Appendix C for explanation of 10^{-7}.

TABLE 13

COMPUTER OUTPUT STATISTICS

1 Independent Variable	2 B Coefficient	3 Equation F-Value After Variable Entry	4 F-Critical Value At .05 Alpha	5 R^2 After Variable Entry
TEMP	251.4	4.16	4.03	.073
NATWAT	58.3	4.10	3.18	.136
OPERMED	-20.3	3.28	2.80	.162
MIGRTE	310.4	3.01	2.57	.194
SHELTER	-37.1	3.06	2.41	.248
PRECIP	-108.1	2.98	2.31	.271
ARTWAT	27.4	2.71	2.23	.288
SCARTEC	67.6	2.46	2.16	.300
ELIMTEC	-32.9	2.19	2.11	.305
NATFOOD	10.0	1.96	2.06	.308
(Constant)	-742.0			

would cause a decrease in the value of STRAT. The model shows that when sheltering and precipitation are increased, the bird/aircraft strike rate decreases, which does not coincide to these actual occurrences in nature. Also, the variable ARTFOOD was not entered by the computer into the equation because its F-level was too low for further computations (33:345). This visual inspection and the aforementioned unexpected relationships caused questions as to the validity of the overall model.

The model was statistically tested for validity as a good estimator of STRAT at a .05 alpha level and was found to

be statistically insignificant or a poor estimator. Column 3 of Table 13 is the F statistic calculated by the computer after each of the independent variables were entered into the equation. Column 4 is the F-critical value from statistical tables (46:716) for a .05 alpha level. Comparing Column 3 with Column 4, it can be seen that all the F values except for the last one in Column 3 were greater than the F-critical values in Column 4. This comparison shows that with 95 percent confidence that the model was statistically significant until the last variable, NATFOOD, was entered into the equation. Even with NATFOOD in the equation, it is nearly statistically significant. In fact, if a lower confidence level, such as 90 percent (.10 alpha level), had been chosen, the model would have been statistically significant. However, Column 5 shows further evidence of problems with the model. The R^2 values show the percentage of the variation of the dependent variable which is explained by the independent variable in conjunction with the independent variables already in the equation. With all the variables except ARTFOOD in the model, only 30.8 percent of the variation was explained, indicating the model is a poor predictor of the dependent variable (52). Since it was felt that regression analysis was a valid approach in this research, analysis of the data and the method used to quantify the data gave insight into the problems of the model. This analysis will be the subject of the remainder of this section.

As mentioned earlier, the dependent variable, STRAT,

was determined using data from AFISC at Norton Air Force Base. Since before 1978 only the bird/aircraft strikes causing damage greater than $300 were included, it was felt that the value of STRAT for each data set was unrealistically low. In fact, some of the bases which had no bird/aircraft strikes indicated for a particular year on the AFISC computer file were found, through the telephone interviews, to have had a number of bird/aircraft strikes, sometimes over 100, for that particular year. In most cases, this was because no damage had been caused. Although the base personnel did have the total number of bird/aircraft strikes for a particular year at their base, they could not readily give the number that occurred in the airbase traffic pattern. For this reason, the AFISC data files had to be relied on completely for this research. Now that AFISC is collecting all the Air Force bird/aircraft strikes that occur, this should not be a problem for future research studies in this area.

The data obtained for the independent variables tended to be general rather than specific, causing difficulty in quantifying some of the factors. The BASH studies, although more than adequate for the purpose they were intended, tended to be general in their analysis. The assumption was made, unless stated in the study itself, that prior to a BASH study the base had not been doing anything to reduce bird/aircraft strike problems. The telephone interviews revealed that this was not the case at some of the bases and that many things had been done prior to the BASH team study, even though no mention

of it was made in the published BASH study. In these instances, as much data as possible was collected from the telephone interview. Except for the telephone interviews, the BASH team studies were found to be the best source of data for each of the bases studied. Visiting each base to obtain more specific data was limited by the funds available for travel and the time allowed for this research.

There also were problems with the method used to quantify the data into the variables. The ratings used did not allow for any factor to obtain a value larger than three. This caused a factor that had been subjectively determined to be significant in influencing the bird/aircraft strike problem to be equal to another factor that was not as significant a contributor. Another possible problem was lumping all the factors into variables. It was felt that a possible regression with all the factors may reveal a better model. This was not accomplished in this research because of the quantifying problem mentioned above. It was found, through the telephone interviews, that most of the bases had their worst bird/aircraft strike problems during certain seasons of the year. Possibly if each year had been divided into the four seasons and data could have been collected for each, a better association of the influencing factors to the bird/aircraft strike rate could be found. Dividing the data into seasons was limited in this research because of the lack of a data resource to allow it to be done.

Solutions for all the above problems were not attempted

in this research because of the lack of an adequate data base to accomplish them or the limited time remaining for research after they were discovered. Finding the solutions to these problems should develop a statistically significant model that will explain a large portion of the variation in the dependent variable. Recommendations for follow-on research studies in this area will be discussed further in Chapter V.

External Validation

As mentioned in Chapter III, if the model turned out to be a valid predictor of a base's strike rate, then it was not necessary to show external validity for the model. One example of why the model need not be externally validated is shown by one of the five randomly selected sets of variables. The variables for Columbus AFB for the year 1976 made up one of these data sets. When the values for the variables were placed in the model obtained from the multiple linear regression, the strike rate that was predicted was 356×10^{-7} strikes per activity. The actual count for that base for that year was 87×10^{-7} strikes per activity. This example showed the model to be a poor predictor of the strike rate for a particular year. It was, however, a better predictor of the base's mean strike rate for the five years under study. Columbus had a five-year mean strike rate of 334×10^{-7} strikes per activity. Table 14 shows a summary of the predicted strike rates, the actual strike rates, and the five-year mean strike rates for each of the five cases randomly extracted for the purpose of

TABLE 14

STRIKE RATE SUMMARY ON THE FIVE EXTRACTED DATA SETS

Base	Year	Strike Rates ($X\ 10^{-7}$ Strikes/Activity)		
		From Model	Actual	Five-Year Mean
Columbus	1976	356	87	334
Kelly	1977	103	191	186
Malmstrom	1977	63	311	114
Minot	1976	22	184	84
Travis	1976	245	207	183

external validation.

In four of the five cases listed in Table 14, the model predicted a strike rate closer to the five-year mean than to the actual strike rate for a year for which it was supposed to be predicting. One note, however, should be made here. The probability of a bird/aircraft strike, which here has been labeled strike rate, is of such a small magnitude that a single strike can raise the actual strike rate a significant amount on this scale. For example, the five-year mean strike rate of $114\ X\ 10^{-7}$ strikes per activity for Malmstrom only represents two bird/aircraft strikes for that entire five-year period (see Appendix C). This very small magnitude of occurrence of the event is probably one of the main reasons for the inability of the model to predict the strike rate for a particular year.

When more information is added, as in the five-year mean, the model becomes a better predictor of the strike rate since the sensitivity of the strike rate to one or two bird/aircraft strikes is reduced. For this reason, this type of model might be more appropriate when used to discuss longer-term average strike rates than just one year, as is the case in the linear regression model presented herein.

The Model as a Managerial Tool

In accordance with the third research question as listed in Chapter II, and as part of the explanation of how the model developed in this research could be used in a managerial decision that affects the probability of a bird/aircraft strike, two hypothetical examples will be shown which will show how the model could be used. Many situations on an Air Force base have considerations which will impact the BASH of the airdrome associated with that base. For example, managers make the decision whether to spend extra money on grounds maintenance, clean drainage ditches, drain and fill a pond, cut down trees, or remove food sources available to the birds. Managers also may decide whether they can change flying operations in order to avoid flying at times when bird activity is at its greatest. Some of these decisions cost money to implement while others do not. Even though the model that was developed in this research was not a very good predictor of the strike rate for a base, the researchers felt that this was a definite step in the right direction to the development of the intended

managerial tool.

A good example of how the model can be used in managerial decision-making is the flight scheduling at Columbus Air Force Base. It was recommended by the BASH team that aircraft should be scheduled "to avoid daily flights of the birds . . . if major flocks routinely fly through the traffic pattern at Columbus AFB [21:14]." In discussing this recommendation with safety personnel on the base (35), it was related that the base had implemented this recommendation. It would have been possible, had the model been significant, to predict the impact that such an action would have had on the strike rate. When such an operational procedure change was implemented, the factor relating to changes in flight scheduling would be increased by a certain amount and, therefore, the variable OPERMED would also be increased by that amount. According to the developed model, such an increase in emphasis in this area would decrease the strike rate 20.3×10^{-7} strikes per activity for every unit of increase in emphasis as determined by Table 11. If the model were more reliable, it would have been possible to predict that the action would decrease the raw numbers of strikes by about half a bird/aircraft strike. On this base which had a five-year average of 7.4 strikes, this reduction of 0.5 strikes per year would probably be well worth the effort necessary to make this operational change. The cost of such a change would probably be quite minimal and easy to bring about. Thus, in this situation the model could have been used to show that such an operational change would have the particular

impact on the strike rate that was desired.

The second example came from Malmstrom AFB. The BASH team recommended that several low areas on the base be filled in so as not to collect water, providing a bird attractant to waterfowl that frequent this particular area (14:9). Such a recommendation would cost a certain amount of money. By using the model again in a way similar to that just discussed about Columbus AFB, it could have been estimated that for every reduction in the factor relating to natural water on the base, an increase of 58.3×10^{-7} strikes per activity for that base for that year would result. This reduction would only reduce the raw numbers of bird/aircraft strikes by 0.16 strikes according to the model and to the number of aircraft activities at Malmstrom in 1978. This 0.16 strikes would not make a lot of difference in the already low rate of two bird/aircraft strikes in the last five years. Because of the effort required to implement this recommendation and because of the low relative return involved in additional safety savings, such a modification might be unnecessary. In addition to this information that the manager would now have, he can also perhaps get information on the particular aircraft that use that base. If these aircraft are not particularly sensitive to bird/aircraft strikes, then this might be additional support to influence the manager not to proceed with the recommendation to fill in those low-standing water areas.

Two examples have been shown where the model could be used in the managerial decision-making process. One example

showed that the recommendations of the BASH team should have been implemented while the other example showed that perhaps it shouldn't. This was assuming that the model developed was a more accurate predictor than the one developed in this thesis. In summary, such a model could add additional information for the manager in the Air Force that could be used to evaluate different methods of bird/aircraft hazard reduction.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Though a specific model was not developed from this effort, some general conclusions can be drawn.

Research Question 1

As discussed earlier, numerous BASH team studies have revealed the environmental factors that influence the potential for a bird/aircraft strike. These factors were catalogued into variables in Chapter II and shown in detail in Tables 1 through 11. The telephone interviews further verified these factors and did not reveal any additional factors which were not included in these tables. Therefore, it is concluded that this research has identified the environmental factors which influence the potential for a bird/aircraft strike.

Research Question 2

Since the stepwise inclusion format of the computer listed the independent variables in order of significance, a statistically significant model would have shown the most significant factors that affected bird/aircraft strike rate. From this list, the affect of changing certain environmental factors or operational procedures on the probability of a bird/aircraft strike

could have been determined. Because of the problems with the model in this research, the ordering shown in Table 13 was considered questionable and the probabilities could not be determined.

The telephone interviews revealed that changing certain environmental factors and operational procedures have caused an effect on the possibility of a bird/aircraft strike. The most effective environmental change reported in the majority of the interviews was maintaining the grass height at levels recommended by the BASH team study (8; 17; 18; 29; 30; 35; 36; 47). Elimination techniques were rarely used and scaring techniques, when used, were found to be ineffective (8; 17; 29; 35; 47). Also, not one of the bases interviewed owned or used remote scaring devices. "Bird Watch" programs have been found to be the most effective operational procedure at all the bases. Each base interviewed had one or two environmental and/or operational changes which have been instrumental in reducing the possibility of bird/aircraft strikes. Because of this, it was concluded that the development of a statistically significant model is certainly conceivable.

Research Question 3

The general methodology used in this research effort seemed to be the correct approach for ultimately providing a managerial decision-making tool. As discussed in Chapter IV, the method of data quantification was not adequate, and if more research is done to develop the managerial tool desired,

a different scheme of data quantification of the independent variables would be required. The order that these variables were entered into the stepwise progression, as well as the magnitude and algebraic sign of the coefficients of the variables in the model, provide a clue to the researcher on a possible way to better quantify the values of the variables. The model developed in this research gives other researchers information on how not to proceed as well as how to proceed with further research in developing a managerial tool for assessing different bird/aircraft strike hazard reduction methods.

Recommendations

During this research, some areas were identified which are presented for further study and consideration. In doing so, we attempt to share our findings so that others may use the conclusions and recommendations as a starting point for other research.

1. Commanders and supervisors should be made aware of the consequences of disregarding those recommendations made by experts who have determined certain methods whereby bird/aircraft strike hazards can be reduced. This is especially true for simple environmental manipulations and operating procedure changes that can be of great benefit for very little expense.

2. Ensure that the present format and requirement for reporting all bird/aircraft strikes, no matter what the cost of the damage, is maintained to provide the necessary data for

future research in this area.

3. Air Force bases should be required to maintain standardized, Air Force-wide data on factors that relate to the bird/aircraft strike potential such as those used in this research. Such data is needed to report changes in those factors that relate to the hazard so that future researchers will be able to identify operational and environmental conditions of particular air bases.

4. Develop a system for quantifying the factors affecting bird/aircraft strike hazard potential. This system should provide at least nominal data and, preferably, ordinal data on the relative weights of such factors. The method used in this research was such an attempt and could be revised with additional research effort.

5. Once sufficient data has been accumulated from recommendations 2, 3, and 4 above, the data should be analyzed using frequency and cross-tabulation techniques to determine interrelationships among variables and factors.

6. In addition to the cross-tabulation analysis, a multiple linear regression model should be accomplished similar to the one in this research with the data developed from these recommendations.

7. Various methods of organizing the dependent variables, strike rate, should be tried with the regression in recommendation 6. A more meaningful model might be developed if the strike rate were averaged over a shorter time period, such as months or seasons of the year.

8. Develop a more standard, Air Force-wide "Bird Watch" program for warning pilots of bird/aircraft strike hazards that can still be tailored to the needs of individual bases.

APPENDIX A

REGRESSION DATA AND SOURCES

Year	STRAT*	NATWAT	ARTWAT	NATFOOD	ARTFOOD	SHELTER	MIGRATE	PRECIP	TEMP	SCATTEC	ELIMTEC	OPERMED	Data Sources
	Cannon AFB (BASH Study - May 1976)												
'74	342	2	8	7	8	4	1	1	3	0	1	15	
75	83	2	8	7	8	4	1	1	3	0	1	15	
76	75	2	9	5	6	3	1	1	3	0	2	15	(20; 30; 43)
77	0	2	9	5	6	3	1	1	3	0	2	15	
78	0	2	9	5	6	3	1	1	3	0	2	15	
	Columbus AFB (BASH Study - May 1977)												
74	293	9	3	3	1	8	1	3	3	0	0	0	
75	576	9	3	3	1	8	1	3	3	0	0	0	
76**	87	9	3	3	1	8	1	3	3	0	0	0	(21; 35; 43)
77	479	9	3	2	1	4	1	3	3	1	2	14	
78	237	9	3	2	1	4	1	3	3	1	2	14	
	Dover AFB (BASH Study - April 1978)												
74	199	11	3	4	3	8	1	3	2	0	0	0	
75	72	11	3	4	3	8	1	3	2	0	0	0	
76	154	11	3	4	3	8	1	3	2	0	0	0	(12; 18; 43)
77	141	11	3	4	3	8	1	3	2	0	0	0	
78	77	11	2	3	3	7	1	3	2	1	1	5	
	Edwards AFB (BASH Study - June 1976)												
74	175	0	9	3	3	3	0	0	3	0	2	1	
75	97	0	9	3	3	3	0	0	3	0	2	1	
76	0	0	8	3	3	3	0	0	3	0	2	1	(13; 5; 37; 43)
77	66	0	8	3	3	3	0	0	3	0	2	1	
78	56	0	8	5	3	3	0	0	3	0	2	1	

*The dependent variable, STRAT, is explained in Appendix C.

**Indicates data points randomly removed prior to the multiple regression being accomplished

Year	STRAT	NATWAT	ARTWAT	NATFOOD	ARTFOOD	SHELTER	MIGRTE	PRECIP	TEMP	SCARTEC	ELIMTEC	OPERMED	Data Sources
	Kelly AFB (BASH Study - December 1976)												
74	571	4	3	9	6	9	1	2	3	0	0	1	
75	119	4	3	9	6	9	1	2	3	0	0	1	
76	48	4	3	9	6	9	1	2	3	0	0	1	(10; 51; 43)
77*	191	4	1	9	3	9	1	2	3	0	0	1	
78	0	4	1	9	3	9	1	2	3	0	0	1	
	Laughlin AFB (BASH Study - September 1977)												
74	356	5	3	9	3	9	1	1	3	0	0	4	
75	230	5	3	9	3	9	1	1	3	0	0	4	
76	165	5	3	9	3	9	1	1	3	0	0	4	(25; 47; 43)
77	264	5	3	9	3	9	1	1	3	0	0	4	
78	110	5	3	7	3	8	1	1	3	1	0	15	
	Malmstrom AFB (BASH Study - September 1977)												
74	0	8	0	7	5	5	1	1	1	0	0	0	
75	0	8	0	7	5	5	1	1	1	0	0	0	
76	257	8	0	7	5	5	1	1	1	0	0	0	(14: 36; 43)
77*	311	8	0	7	5	5	1	1	1	0	0	0	
78	0	8	0	7	3	4	1	1	1	0	0	1	
	Minot AFB (BASH Study - September 1977)												
74	0	8	6	5	8	10	1	1	1	0	0	0	
75	129	8	6	5	8	10	1	1	1	0	0	0	
76*	184	8	6	5	8	10	1	1	1	0	0	0	(15; 27; 43)
77	0	8	6	5	8	10	1	1	1	0	0	0	
78	108	8	6	5	8	10	1	1	1	1	1	4	

*Indicates data points randomly removed prior to the multiple regression being accomplished.

Year	STRAT	NATWAT	ARTWAT	NATFOOD	ARTFOOD	SHELTET	MIGRTE	PRECIP	TEMP	SCARTEC	ELIMTEC	OPERMED	Data Sources
	Moody AFB (BASH Study - October 1976)												
'74	704	8	0	6	6	6	1	3	3	1	0	3	
75	367	8	0	6	6	6	1	3	3	1	0	3	
76	0	8	0	6	6	6	1	3	3	1	0	3	(26; 29 43)
77	236	8	0	4	6	6	1	3	3	1	0	8	
78	0	8	0	4	6	6	1	3	3	1	0	8	
	Myrtle Beach AFB (BASH Study - August 1976)												
74	120	9	3	6	6	12	1	3	3	0	0	4	
75	135	9	3	6	6	12	1	3	3	0	0	4	
76	56	9	3	6	6	12	1	3	3	0	0	4	(23; 8 43)
77	0	9	1	6	5	10	1	3	3	2	1	11	
78	70	9	1	6	5	10	1	3	3	2	1	11	
	Randolph AFB (BASH Study - July 1976)												
74	338	9	3	9	6	11	1	2	3	0	2	2	
75	260	9	3	9	6	11	1	2	3	0	2	2	
76	90	9	3	9	6	11	1	2	3	0	2	2	(24; 41 43)
77	244	9	3	9	6	11	1	2	3	0	2	11	
78	165	9	3	9	6	11	1	2	3	0	2	11	
	Travis AFB (BASH Study - December 1976)												
74	288	6	7	7	6	8	1	1	2	0	1	0	
75	228	6	7	7	6	8	1	1	2	0	1	0	
76*	207	6	7	7	6	8	1	1	2	0	1	0	(22; 17 43)
77	40	6	3	4	6	6	1	1	2	1	1	6	
78	154	6	3	4	6	6	1	1	2	1	1	6	

*Indicates data points randomly removed prior to the multiple regression being accomplished.

APPENDIX B

SPSS COMPUTER PROGRAM

```
100##S,J :,8,16;;,16
110$:IDENT:WP1186,SMITH/JORGENSEN,AFIT/79B
120$:SELECT:SPSS/SPSS
130RUN NAME; THESIS STUDY - MULTIPLE LINEAR REGRESSION
140VARIABLE LIST; STRAT, NATWAT, ARTWAT,NATFOOD/
150;ARTFOOD,SHELTER,MIGRTE,PRECIP,TEMP,SCARTEC/
160;ELIMTEC,OPERMED
170INPUT FORMAT;FREEFIELD
180INPUT MEDIUM;CARD
190N OF CASES;55
200VAR LABELS;STRAT, ANNUAL STRIKE RATE AT BASE/
210;NATWAT, NATURAL WATER BODIES/
220;ARTWAT, ARTIFICIAL WATER BODIES/
230;NATFOOD, NATURAL FOODS/
240;ARTFOOD, ARTIFICIAL FOODS/
250;SHELTER, SHELTERING-NATURAL AND ARTIFICIAL/
260;MIGRTE, MIGRATORY ROUTE/
270;PRECIP, ANNUAL PRECIPITATION
280;TEMP, ANNUAL AVERAGE TEMPERATURE
290;SCARTEC, SCARING TECHNIQUES/
300;ELIMTEC, ELIMINATION TECHNIQUES/
310;OPERMED,OPERATIONAL METHODS/
320REGRESSION;VARIABLES=STRAT,NATWAT
330;ARTWAT,NATFOOD,ARTFOOD,SHELTER
340;MIGRTE,PRECIP,TEMP,SCARTEC,ELIMTEC,OPERMED/
350;REGRESSION=STRAT WITH NATWAT, ARTWAT
360;NATFOOD,ARTFOOD,SHELTER,MIGRTE,PRECIP
370;TEMP,SCARTEC,ELIMTEC,OPERMED (1) RESID=0
380STATISTICS;1,2,4,5,6
390READ INPUT DATA
400$:SELECTA:BIRDATA,R
410SCATTERGRAM:STRAT(-1,600) WITH NATWAT(-1,12)
420;ARTWAT(0,10),NATFOOD(0,10),ARTFOOD(0,10)
430;SHELTER(0,13),MIGRTE(-1,2),PRECIP(-1,4)
440;TEMP(-1,4),SCARTEC(-1,3),ELIMTEC(-1,3),OPERMED(0,15)
450PEARSON CORR;STRAT, NATWAT,ARTWAT,NATFOOD,ARTFOOD
460;SHELTER,MIGRTE,PRECIP,TEMP,SCARTEC,ELIMTEC,OPERMED
470OPTIONS;3
480STATISTICS;2
490FINISH
500$:ENDJOB
```

APPENDIX C

SUMMARY OF DATA FOR COMPUTING
STRIKE RATE

Air Force Base	Year	Bird/ Aircraft Strikes	Total Airdrome Activities	Strike Rate (strikes/activity) (X 10^{-7})*
Cannon	1974	4	117,102	342
	1975	1	120,616	83
	1976	1	134,047	75
	1977	0	226,015	0
	1978	0	77,789	0
Columbus	1974	7	239,209	293
	1975	12	208,241	576
	1976	2	229,039	87
	1977	10	208,632	479
	1978	6	253,141	237
Dover	1974	3	150,627	199
	1975	1	139,042	72
	1976	3	194,335	154
	1977	2	142,131	141
	1978	1	130,307	77
Edwards	1974	2	114,329	175
	1975	1	103,109	97
	1976	0	138,195	0
	1977	1	152,497	66
	1978	1	178,140	56
Kelly	1974	10	175,114	571
	1975	2	167,783	119
	1976	1	208,426	48
	1977	3	157,149	191
	1978	0	144,286	0
Laughlin	1974	8	224,882	356
	1975	5	217,249	230
	1976	4	241,735	165
	1977	7	265,372	264
	1978	3	273,760	110

*Note: Strike Rate listed here and as put into the computer would need to be multiplied by 10^{-7} to get the actual strike rate. This was done to avoid working with such small numbers.

Air Force Base	Year	Bird/ Aircraft Strikes	Total Airdrome Activities	Strike Rate (strikes/activity) (X 10^{-7})*
Malmstrom	1974	0	38,621	0
	1975	0	30,964	0
	1976	1	38,892	257
	1977	1	32,199	311
	1978	0	27,970	0
Minot	1974	0	79,589	0
	1975	1	77,454	129
	1976	2	108,456	184
	1977	0	90,363	0
	1978	1	92,248	108
Moody	1974	12	170,487	704
	1975	6	163,697	367
	1976	0	109,140	0
	1977	2	84,816	236
	1978	0	94,795	0
Myrtle Beach	1974	2	167,137	120
	1975	2	148,135	135
	1976	1	177,160	56
	1977	0	133,849	0
	1978	1	142,428	70
Randolph	1974	11	325,613	338
	1975	7	269,495	260
	1976	3	332,252	90
	1977	6	245,486	244
	1978	4	242,184	165
Travis	1974	4	138,731	288
	1975	5	219,280	228
	1976	7	337,572	207
	1977	1	248,720	40
	1978	4	259,859	154

*Note: Strike Rate listed here and as put into the computer would need to be multiplied by 10^{-7} to get the actual strike rate. This was done to avoid working with such small numbers.

SELECTED BIBLIOGRAPHY

A. REFERENCES CITED

1. Air Force Inspection and Safety Center. "All Birdstrike Mishaps in 1978." Computer Printout, SEFF, Norton AFB CA, February 1979.

2. ________. "Birdstrike Mishaps in 1974 thru 1977." Computer Printout, SEFF, Norton AFB CA, April 1979.

3. Air Traffic Service. "ATC Annual Summary Report for 1974 Thru 1978." Computer Printout, The Air Force Communication Service, Scott AFB IL, 5 July 1979

4. Aldrich, John W., Chandler S. Robbins, and Walter W. Dykstra. Bird Hazard to Aircraft. Wildlife Leaflet 429, U.S. Department of the Interior. Washington: Government Printing Office, January 1961.

5. Baker, Jim, GS-12. Staff Environmental Coordinator, Edwards AFB CA. Telephone interview. 10 July 1979

6. Blokpoel, Hans. Bird Hazards to Aircraft. Canada: Clark, Irwin and Company Limited, 1976.

7. Boulter, Lieutenant Michael J., USAF, Second Lieutenant George E. Meyer, USAF, and Sergeant Dennis E. Compton, USAF. Preliminary Evaluation of the Bird-Aircraft Collision Hazard at Ellington AFB, Texas. Report No. AFWL-TN-73-014, Air Force Weapons Laboratory, Kirtland AFB NM, April 1973.

8. Brown, Captain David L., USAF. Wing Flying Safety Officer, Myrtle Beach AFB SC. Telephone interview. 2 July 1979.

9. Clark, Captain Larry T., USAF. An Evaluation of the Bird/Aircraft Strike Hazard at Rickenbacker AFB, Ohio. Report No. AFCEC-TM-76-8, Air Force Civil Engineering Center, Tyndall AFB FL, August 1976.

10. ________, Tech Sergeant Ernest R. Godsey, USAF, and Airman William H. Niemeier, USAF. An Evaluation of the Bird/Aircraft Strike Hazard at Kelly Air Force Base, Texas. Report No. AFCEC/TM-76-17, Air Force Civil Engineering Center, Tyndall AFB FL, July 1976.

11. ________ and Cadet First Class James J. Grupp, USAFA. An Evaluation of the Bird/Aircraft Strike Hazard at Hulman Field ANGB, Indiana. Report No. AFCEC-M-3-77, Air Force Civil Engineering Center, Tyndall AFB FL, June 1977.

12. ________, Captain Joseph M. Lavey, USAF, and Lieutenant James S. Kent, USAF. An Evaluation of the Bird/Aircraft Strike Hazard at Dover Air Force Base, Delaware. Report No. AFCEC-TM-1-78, Air Force Civil Engineering Center, Tyndall AFB FL, April 1978.

13. ________ and First Lieutenant Portia R. McCracken, USAF. An Evaluation of the Bird/Aircraft Strike Hazard at Edwards Air Force Base, California. Report No. AFCEC/TM-76-3, Air Force Civil Engineering Center, Tyndall AFB FL, 18 June 1976.

14. ________ and Airman Richard D. Smedley, Jr., USAF. An Evaluation of the Bird/Aircraft Strike Hazard at Malmstrom AFB, MT. Report No. AFCEC-M-9-77, Air Force Civil Engineering Center, Tyndall AFB FL, September 1977.

15. ________, Second Lieutenant Roderick T. Thornton, USAF, and Airman Richard D. Smedley, Jr., USAF. An Evaluation of the Bird/Aircraft Strike Hazard at Minot Air Force Base, North Dakota. Report No. AFCEC-M-8-77, Air Force Civil Engineering Center, Tyndall AFB FL, September 1977.

16. Collum, Technical Sergeant Robert O., USAF, and Brother Edwin Mattingly. Preliminary Evaluation of Bird/Aircraft Strike Hazard at Hill AFB, Utah. Report No. AFWL-DE-TN-73-026, Air Force Weapons Laboratory, Kirtland AFB NM, October 1973.

17. Doten, Captain Gregory A., USAF. C-5A Flying Safety Officer, Travis AFB CA. Telephone interview. 3 July 1979.

18. Findley, Captain George W., USAF. Chief of Flying Safety, Dover AFB DE. Telephone interview. 2 July 1979.

19. Flight Safety Division. USAF Aircraft Collisions with Birds. Study No. 12-67, Norton AFB CA, 1967.

20. Harrison, Captain Michael J., USAF, Captain Larry T. Clark, USAF, and Joan Scott. An Evaluation of the Bird/Aircraft Strike Hazard at Cannon AFB, New Mexico. Report No. AFCEC/EV-TM-76-1, Air Force Civil Engineering Center, Tyndall AFB FL, 17 March 1976.

21. ________, Technical Sergeant Ernest R. Godsey, USAF, and Sergeant Claude L. Scott, USAF. Bird/Aircraft Strike Hazard Survey Columbus AFB, Mississippi. Report No. AFCEC-TM-77-06, Air Force Civil Engineering Center, Tyndall AFB FL, May 1977.

22. ________, Captain Portia R. McCracken, USAF, and Master Sergeant Ernest R. Godsey, USAF. An Evaluation of the Bird/Aircraft Strike Hazard at Travis Air Force Base, California. Report No. AFCEC-M-1-77, Air Force Civil Engineering Center, Tyndall AFB FL, December 1976.

23. ________, First Lieutenant Portia R. McCracken, USAF, and Sergeant Claude L. Scott, USAF. Bird/Aircraft Strike Hazard Survey Myrtle Beach Air Force Base, South Carolina. Report No. AFCEC-TM-76-11, Air Force Civil Engineering Center, Tyndall AFB FL, August 1976.

24. ________, First Lieutenant Portia R. McCracken, USAF, and Joan Scott. An Evaluation of the Bird/Aircraft Strike Hazard at Randolph Air Force Base, Texas. Report No. AFCEC-TM-76-14, Air Force Civil Engineering Center, Tyndall AFB FL, July 1976.

25. ________, Airman William H. Niemeier, USAF, and Cadet First Class James J. Grupp, USAFA. An Evaluation of the Bird/Aircraft Strike Hazard at Laughlin Air Force Base, Texas (ATC). Report No. AFCEC-M-5-77, Air Force Civil Engineering Center, Tyndall AFB FL, September 1977.

26. ________ and Sergeant Claude L. Scott, USAF. Bird/Aircraft Strike Hazard Survey Moody AFB, Ga. Report No. AFCEC-TM-77-2, Air Force Civil Engineering Center, Tyndall AFB FL, October 1976.

27. Hoekstra, Captain Alvin C., USAF. Wing Flying Safety Officer, Minot AFB ND. Telephone interview. 29 June 1979.

28. Houle, Major John R., USAF. "Analysis and Prevention of Bird Strikes by Jet Aircraft." Unpublished research. Report No. 1165-77, Air Command and Staff College, Maxwell AFB AL, March 1977.

29. Jonah, Captain Craig M., USAF. Chief of Flying Safety, Moody AFB GA. Telephone interview. 2 July 1979.

30. Kroehl, Captain Bruce, USAF. Wing Flying Safety Officer, Cannon AFB NM. Telephone interview. 3 July 1979.

31. Meyer, First Lieutenant George E., USAF, First Lieutenant Michael J. Boulter, USAF, and Sergeant Dennis E. Compton, USAF. An Evaluation of the Bird/Aircraft Strike Hazard at Reese AFB, Texas. Report No. AFWL-DE-TN-73-017, Air Force Weapons Laboratory, Kirtland AFB NM, January 1973.

32. Meyer, Captain George E., USAF, and Sergeant Dennis E. Compton, USAF. Preliminary Evaluation of Bird/Aircraft Strike Hazard at Williams AFB, Arizona. Project No. 683M3E09, Air Force Weapons Laboratory, Kirtland AFB NM, April 1973.

33. Nie, Norman H., and others. Statistical Package for the Social Sciences (SPSS). 2d ed. New York: McGraw-Hill Book Company, 1975.

34. Pyne, Lieutenant Colonel Frank B. "Crew Protection," Aerospace Safety, March 1976, pp. 24-25.

35. Riley, Master Sergeant Thomas R., USAF. Air Field Management, Malmstrom AFB MT. Telephone interview. 2 July 1979.

36. Row, Captain Charles E., USAF. Chief Air Field Management, Malmstrom AFB MT. Telephone interview. 2 July 1979.

37. Sandmeyer, Master Sergeant Daniel W., USAF. Chief Weather Forecaster, Edwards AFB CA. Telephone interview. 2 July 1979.

38. Short, Captain Jeff, USAF. Chief, Bird/Aircraft Strike Hazard (BASH) Team, Tyndall AFB FL. Telephone interview. 16 January 1979.

39. Siegel, Sidney. Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill Book Company, 1956.

40. Sobieralski, Sergeant Ronald J., USAF. Ecological Aspects of Bird-Aircraft Strike Hazards. Technical Report No. AFWL-7R-71-94, Air Force Weapons Laboratory, Kirtland AFB NM, March 1972.

41. Stone, Captain Robert D., USAF. Wing Flying Safety Officer, Randolph AFB TX. Telephone interview. 3 July 1979.

42. Sugg, R. W. An Investigation Into Bird Densities Which Might Be Encountered by Aircraft During Take-Off and Landing. S & T Memo 6/65, Technical Information and Library Services, Ministry of Aviation, U.K., April 1965.

43. U.S. Bureau of the Census. County and City Data Book. Washington: Government Printing Office, 1967.

44. U.S. Department of the Air Force. The Bird Strike Hazard Reduction Program. AFR 127-15. Washington: Government Printing Office, 23 January 1978.

45. U.S. Department of the Interior. Control of Birds On and Around Airports. SRDS Report No. RD-68-62, Washington D.C., October 1968.

46. Wonnacott, Thomas H., and Ronald J. Wonnacott. Introductory Statistics for Business and Economics. 2d ed. New York: John Wiley & Sons, 1977.

47. Woodland, Captain David B., USAF. Wing Flying Safety Officer, Laughlin AFB TX. Telephone interview. 3 July 1979.

48. Wooten, Captain Rutherford C., Jr., USAF, and John P. Nemergut. An Evaluation of the Bird/Aircraft Strike Hazard at the Hughes Airport Culver City, Ca. Report No. AFWL-DE-TN-74-011, Air Force Weapons Laboratory, Kirtland AFB NM, April 1975.

49. ________ and Sergeant Ronald J. Sobieralski, USAF. An Evaluation of Bird/Aircraft Strike Hazard at Kincheloe Air Force Base, Michigan. Report No. DE-TN-71-018, Air Force Weapons Laboratory, Kirtland AFB NM, June 1971.

50. ________, Sergeant Ronald J. Sobieralski, USAF, and Airman Robert C. Beason, USAF. An Evaluation of the Bird/Aircraft Strike Hazard at Shemya Air Force Base, Alaska. Report No. DE-TN-71-037, Air Force Weapons Laboratory, Kirtland AFB NM, October 1971.

51. Wright, Lieutenant Colonel Leonard L., USAF. Wing Flying Safety Officer, Kelly AFB TX. Telephone interview. 2 July 1979.

52. Zambo, Major Leslie J., USAF. Assistant Professor of Quantitative Methods, Department of Systems Acquisition Management, Air Force Institute of Technology, School of Systems and Logistics, Wright-Patterson AFB OH. Personal interview conducted 1 August 1979.

B. RELATED SOURCES

Emory, C. William. Business Research Methods. Homewood IL: Richard D. Irwin, Inc., 1976.

The Netherlands Armed Forces Scientific and Technical Documentation and Information Center. Bird Hazards to Aircraft, A Literature Review. TDCK Document 56961, Frederikkazerne, The Netherlands, October 1977.

U.S. Department of the Interior. Establishing Certain Parameters of Hazards to Aircraft by Migrating Birds in the Mississippi Flyway. SRDS Report No. RD-67-67, Washington D.C., November 1967.